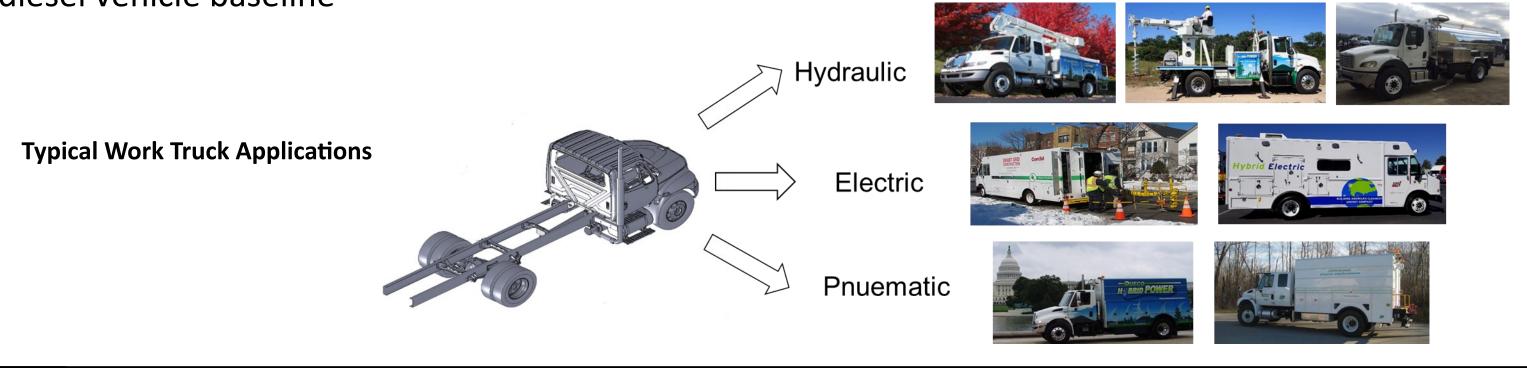
# Development and Demonstration of Medium-and-Heavy-Duty Plug-In Hybrid Work Trucks

# Relevance / Project Objectives

•Relevance: Medium and Heavy duty work trucks consume over 50% of their fuel during stationary jobsite work and idle conditions. Their needs are varied, but they all consume power/fuel to fulfil their primary, stationary work, mission. Current efficiency and hybridization efforts by large truck manufacturers focus on driving efficiency and do not address the stationary fuel savings opportunities of the work truck

•Objective: To develop and demonstrate a modular Plug-in Hybrid Electric (PHEV) Medium-Heavy Duty Work Truck system with greater than 50% reduction in fuel consumption when compared to a conventional diesel vehicle baseline



## Overview

## Timeline

•Start Date: January 19, 2017 •End Date: January 31, 2023 Percent Complete: 85 %

## **Barriers and Technical Targets**

 Fuel efficiency of Medium/Heavy-duty work trucks • Integration of Driving and Jobsite electrification of Medium/Heavy-duty work trucks

 Diverse nature, varied needs and relatively small resultant volumes of individual types of work truck applications

## Budget

•Total Budget -DOE Share \$2,932K -Contractor Share \$2,959K Funding for FY 2021 -\$445K

Funding for FY 2022

-\$96K

## **Partners**

Collaborations

-Odyne Systems—Project Lead –National Renewable Energy Laboratory (NREL)

–Oak Ridge National Laboratory (ORNL) -Allison Transmission

 Ricardo Strategic Consulting -Tacoma Public Utilities

# -South Coast Air Quality Management District

# Milestones

Date	Milestone and Go/No Go	Status		
December, 2021	Prototype Vehicle Performance Validation (Go-No Go)  - Test Chassis demonstrate capability of up to 40% improvement in driving Fuel Economy and >50% reduction in simulated full year fuel consumption in typical work truck duty cycle	Complete: December 2021		
March, 2022	Evaluation Fleet Build and Delivery (10) (Subtask 3.1) - Begin delivery of ten (10) completed prototype evaluation vehicles to fleet participants	Complete: March, 2021		
April, 2022	First Deployment Report (Subtask 3.2) - Report of evaluation fleet status, activity, issues and investigations, and a summary of customer feedback for approximately 3 months of vehicle use	On Track		
July, 2022	Second Deployment Report (Subtask 3.2)	On Track		
October, 2022	Third Deployment Report (Subtask 3.2)	On Track		
December, 2022	Fleet Data Collection, Analysis and Summary (Subtask 3.3) - Summary Evaluation of Data Analysis confirms 50% Reduction in fuel use when compared to a comparable conventional work truck	On Track		

# Approach

## **Hybrid Powertrain**

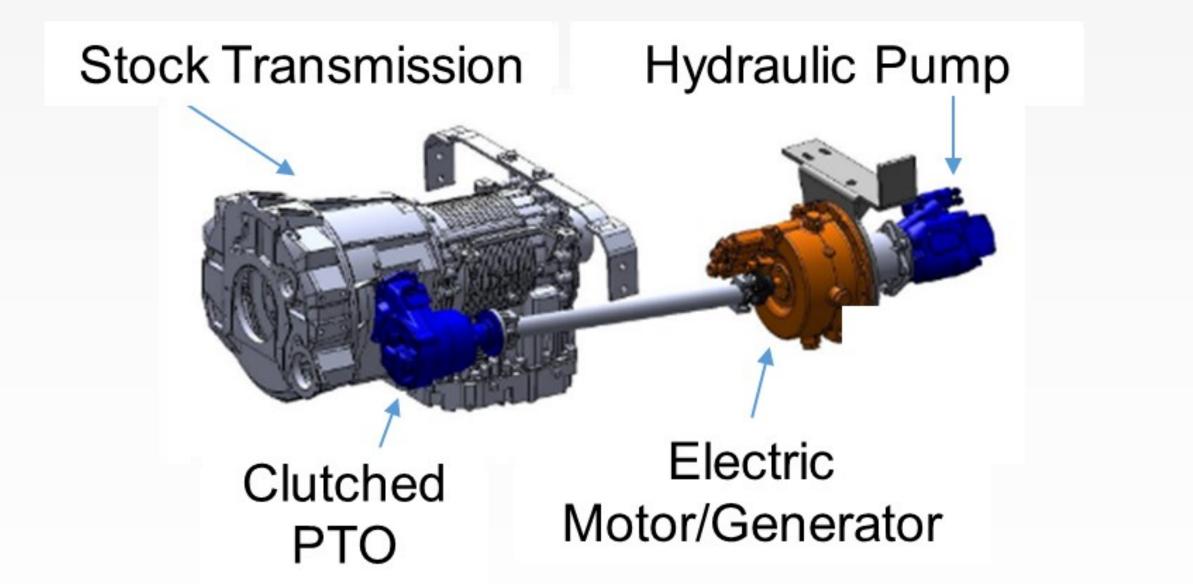
Hybrid Power through existing PTO Port

No Changes to Base Powertrain

• Provides Launch Assist/Regenerative Braking while Driving (PTO Clutch closed)

•Provides All-electric Application Power for stationary work (PTO Clutch open—Engine off)

•Can field charge hybrid battery while maintaining work functions (Clutch closed—Engine on)



Technical Accomplishments, and Progress

## Modular approach allows installation on almost any chassis, application - 3 motor sizes available ●Options include: 2nd Battery, 6 –12 kW Exportable 120/240VAC Power, Heat, A/C) Base Unit ▶ 17.7 kWh Battery System > 3 Motor Options: 92, 207, 337 Nm SAE J1772 L1/L2 Plug-in charging to 6.6 kW With integrated ▶ 12V Chassis Battery support to 2.5 kW Configurable Options 2<sup>nd</sup> Battery (Net 35.4 kWh) 6/12 kW 120/240V Exportable Power Up to 17,000 BTU Auxiliary Air Conditioning **Expansion Battery**

# **Modular Design**

•Base System consists of 3 modules (Motor/Inverter, RESS/Power Electronics, Hybrid Cooling)

▶ Up to 17,000 BTU Auxiliary Low Emi

# Pack with 12 kW

# Remaining Challenges and Barriers

•As the demonstration vehicles begin to work in the real world, Odyne expects to receive new insights from actual operators, fleet managers, and telematics data and will respond as appropriate to the customer and report observations, issues and resolution in the quarterly and final demonstration vehicle reports

 Odyne is already receiving requests to develop and electrified ePTO system for All-electric chassis such as the Freightliner Custom Chassis MT50E and will be applying engineering resources to developing s system to meet this demand

# Summary

## Relevance

 Create Modular Plug-in Hybrid and Electrification system applicable to a large proportion of the Medium and Heavy-Duty work truck market

This system will allow work truck fleets to achieve up to 50% reduction in fuel use which can not be achieved utilizing conventional driving focused hybrid systems

Approach

Work with Chassis OEMs, Final Stage and equipment man-

lufacturers and Fleet customers to understand the diverse

Work with NREL and ORNL to analyze the work truck duty

cycle and optimize the driving and full day hybrid strategies

•Work to continue to reduce cost and size while expanding

the applications for the Odyne PHEV work truck system

needs of the work truck market

# **Technical Accomplishments**

Completed technical and design development of the

Demonstrated through dynamometer testing and duty cycle analysis the ability to achieve greater than 40% improvement in driving fuel economy and predicted greater than 50% reduction in average annual fuel use Built and delivered demonstration fleet

## **Future Work**

 Continue working with Tacoma Public Utilities to deploy land monitor the demonstration vehicles •Complete the installation of Telematics system and analyze Tacoma data for further improvement and optimization Begin to develop next generation work truck system for All -Electric chassis being introduced to the market.

•The Test Chassis was tested at NREL ReFUEL Dynamometer 3 Drive Cycles selected to represent range of work truck operation 2 Hybrid Drive Strategies were evaluated—Mild, Aggressive

 Mild Strategy yielded 9-23% improvement in Fuel Economy Aggressive Strategy yielded 69-75% improvement in Fuel Economy Distance Fuel Used Fuel Used Per MPG Energy Used

**Driving Fuel Economy Improvement** 

Strategy	Duty Cycle	[mi]	[gal]	Mile [gal]	MPG	Improve ment	Per Mile [kWh]
Conventional	UDDS	5.503	0.892	0.162	6.174		0.000
Hybrid Mild	UDDS	5.498	0.813	0.148	6.762	9.5%	0.060
Hybrid Aggressive	UDDS	5.514	0.528	0.096	10.456	69.4%	0.971
Conventional	Odyne Low	3.782	0.809	0.214	4.678		0.000
Hybrid Mild	Odyne Low	3.780	0.656	0.174	5.758	23.1%	0.508
Hybrid Aggressive	Odyne Low	3.788	0.476	0.126	7.954	70.0%	1.675
Conventional	Odyne Medium	8.911	1.431	0.161	6.226		0.000
Hybrid Mild	Odyne Medium	8.907	1.226	0.138	7.266	16.7%	0.197
Hybrid Aggressive	Odyne Medium	8.897	0.815	0.092	10.918	75.4%	1.220

## **Stationary Fuel Savings**

 The Test Chassis was tested in PTO mode utilizing the NREL Transient Stationary Work duty cycle developed earlier in the project •In Comparison, The Test Chassis was tested in Field Recharge mode while generating an equivalent amount of energy •The Hybrid System yielded an 80-99% reduction in Fuel use and

PTO shaft work specific results comparison

## **Average Fuel and Emissions Savings**

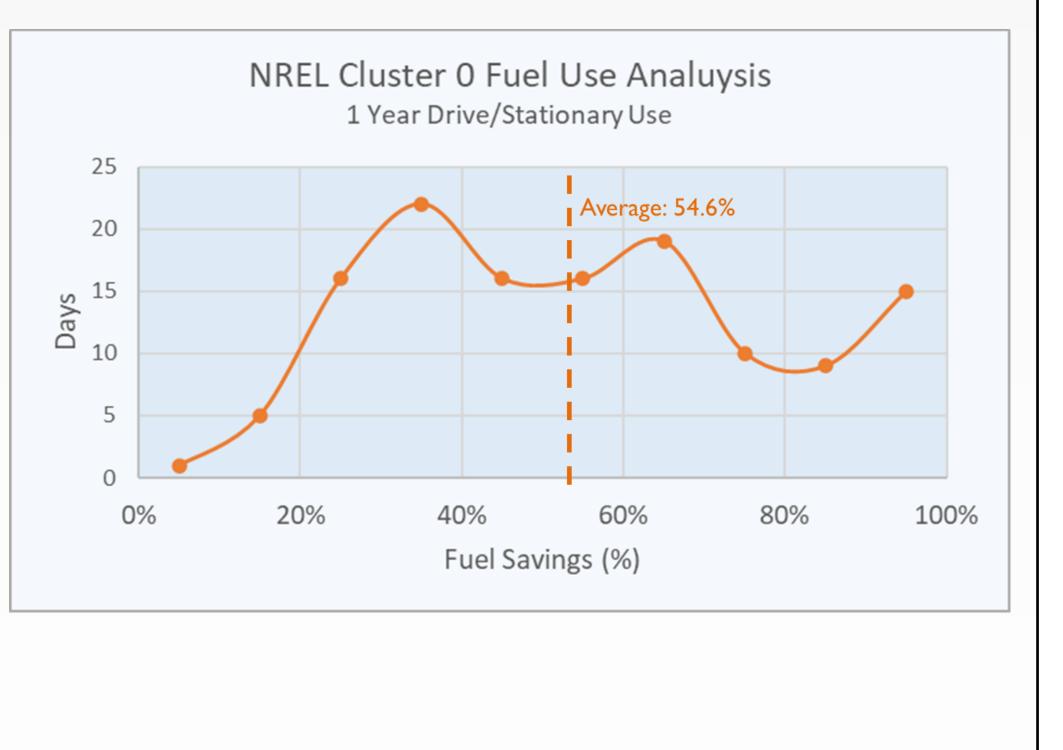
•The Benefits of the Odyne System combine the fuel and emissions savings while driving with the Engine-Off benefits of hybrid jobsite operation.

•The benefits for All-electric Stationary work outweigh the driving

benefits when looking at Gallons saved/kWh The system was optimized for available Battery energy by utilizing the Mild driving strategy, thus reserving more energy for Stationary

 NREL Provided Full-year Drive/Stationary Duty Cycles for analysis •From the Drive and Stationary Dyno data, full year fuel use reduction could be calculated

 The Simulated Full Year Fuel Savings for the Odyne PHEV Work **Truck was 54.6%** 



## **Delivery of Demonstration Vehicles**

 In Early 2022, Odyne began Delivery, Training and Vehicle Support for the Demonstration Fleet at Tacoma Public Utilities (TPU) Odyne will be gathering operator and fleet feedback and will be installing Telematics systems for Objective feedback and refinement during CY 2022



Tacoma Public Utilities Hybrid Step Van

## **Commercial Impact**

 Based on Design, Performance and Integration improvements, as a result of this project, three customers have ordered vehicles in new markets to Odyne



# Collaborations

Organization	Function					
National Renewable Energy Laboratory	<ul> <li>Telematics Duty Cycle Analysis</li> <li>Fuel &amp; Emissions Dynamometer Testing</li> <li>Full Year Fuel Use Modeling</li> </ul>					
Oak Ridge National Laboratory	<ul> <li>Powertrain Simulation, Energy use optimization</li> <li>Hardware-in-Loop (HIL) Powertrain Testing</li> </ul>					
Allison Transmission	<ul> <li>Powertrain and transmission optimization suppor</li> <li>Transmission Control System integration</li> </ul>					
Ricardo Strategic Sourcing	Battery System Sourcing support					
Tacoma Public Utilities	<ul> <li>Provide and field 10 Vehicles to be monitored and evaluated</li> <li>Participate in demo evaluation and feedback</li> </ul>					
South Coast Air Quality Management District	Project cost share					

